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Editor: N. A. Marris, M.Sc., B.Com.
Assistant Editor: M. O'Connor, M.Sc.
Department of Scientific and Industrial Research, Wellington

VOL. 32, SEC. A JUNE 1950 NUMBER 1

STRAINS OF TIMOTHY (*Phleum pratense* L.)

By L. W. GORMAN, Grasslands Division, Department of Scientific and Industrial Research, Palmerston North

Summary

A study has been made of a wide collection of strains of timothy (*Phleum pratense* L.). These have been classified into three distinct groups and the utility of each group has been discussed.

There is some evidence that, in certain districts of New Zealand, where timothy has been grown and seeded for many years, ecological factors have led to intra-specific variation resulting in the evolution of a regional strain.

INTRODUCTION

OF the ten known species in the genus *Phleum*, timothy (*Phleum pratense* L.) is the only one under cultivation, and all except *Phleum alpinum* are indigenous to northern Europe and Asia. *Phleum alpinum* L. emend. Gaud. is considered by Gregor to be restricted to Central Europe.[1]

Timothy is a late maturing grass which thrives in damp situations, but also grows on quite a wide variety of soils, ranging from loams to peats. It is a highly palatable grass requiring a relatively fertile soil, and in addition to growing well in temperate climates, shows to advantage in the colder temperate zones. It has been most extensively used in the United States of America and is regarded as an important species in Canada and in northern Europe. In Sweden it is considered to be the most important of the hay grasses. In these countries it has been grown either alone or with red clover to provide hay crops, but in recent years the increasing interest in grazing pastures has suggested the necessity to locate and develop varieties or strains of timothy specially adapted for use in pasture mixtures.

REVIEW OF LITERATURE

Since the year 1889 plant breeders and geneticists have endeavoured to produce improved varieties or strains of timothy. Research and breeding investigations have been conducted in the United States of America, in Canada, in Sweden and at the Plant Breeding Station at Aberystwyth, Wales. The initial American work was commenced by Hays[2] in 1889, at the University of Minnesota. A few years later Hopkins at the West Virginian Agricultural Experiment Station, selected plants and distributed seed of early, medium

and late varieties. Since 1903 further investigations have been continued at various American Research Stations but most extensively at Cornell University, and by the United States Department of Agriculture in co-operation with the Ohio Agricultural Experiment Station at North Ridgeville and later at Wooster. In Sweden,[3] as the result of breeding and experimental work initiated by the Swedish Seed Association in 1904, varieties specifically adapted to their southern, middle and northern regions have been raised by the Plant Breeding Institute at Svalof and at the branch stations of that Association.

In Canada, selections have been made by the several Canadian Agricultural Colleges and at the Central Experimental Farm at Ottawa. Three distinct strains have been bred by the Welsh Plant Breeding Station and experimental stations in Scotland, Belgium, Denmark, Germany and the Union of Soviet Socialist Republics have investigated the usefulness of local and imported strains of timothy.

In Canada and America[4] particular attention has been given to the selection of leafy and rust resisting hay types with differing times of maturity, whereas plant breeders in the Scandinavian countries have considered winter-hardiness to be of the greatest importance. In the British Isles leafy multi-tillered plants have been selected to withstand close and frequent defoliation.[5]

Timothy as a pasture species, therefore, has attracted considerable attention, and in addition to any improvements such as outlined above, has been the subject of a considerable amount of technical research. Resistance to rust disease has been studied by Bird[6] at the MacDonald College while Smith and Myers[7] at Cornell have analysed yield trials with timothy varieties. Gregor and Sansome[8] at Corstorphine found that cytologically the low growing forms of timothy plants with more or less procumbent stems, such as occur in Great Britain, have 14 chromosomes ($2n$), whereas the plants with longer, more nearly upright stems have 42 chromosomes ($6n$). Gregor[9] at first found these two types inter-sterile, but more recently artificial hybrids have been produced.[10] Sethi[11] in a study of *Phleum, Phalaris* and *Festuca,* found seven as the basic chromosome number in each genus, and in the genus *Phleum,* while different morphological types interbred quite readily, provided they had the same number of chromosomes, diploid and hexaploid types could be crossed only with great difficulty. Muentzing[12] at the Plant Breeding Station at Svalof, Sweden, has observed spontaneous hybrids between *Phleum pratense* and *Phleum alpinum.*

Self-pollination studies by Witte,[13] Valle[14] and other European investigators have shown that the average percentage of florets producing seed is very much less with self-pollination than with natural cross pollination. Hayes and Barker[15] found considerable variability in self fertility of individual timothy plants, and Hayes and Clarke[16] have, in order to obtain vigorous lines which are superior yielding and disease resistant, used selection in self fertilised lines as a means of eliminating undesirable recessive characters. Alternatively, Evans[17] has attained a high degree of uniformity by selecting for several generations under natural conditions allowing open pollination.

Timothy has always been regarded as a useful pasture species in New Zealand, but prior to the commencement of the trials described below, there had not been any detailed experiments to investigate the qualities of the available commercial and selected varieties. For

FIG. 1—Timothy single plants showing type differences in young plants. Left: "Pasture-hay" type. Right: "Hay" type.
Photograph by L. W. Gorman.

this reason a collection of seed samples from as many different sources as possible was gathered together with a view to laying down a series of trials.

EXPERIMENTAL

The range of material available for trial was as set out in the following table:

TABLE I. SAMPLES FOR TRIAL

Origin of Samples	No. of Samples
Commercial (origin unknown)	57
United States of America	23
Great Britain	22
Sweden	7
Canada	3
New Zealand grown	47
Total	159

Included in the samples from Great Britain were selections made by the Welsh Plant Breeding Station, and as these were known to be types selected for pasture purposes they were taken as the standards of comparison. Trials carried out by the author have consisted of row tests and single plant observations. In the former, the samples received were sown in rows, ten links long, alongside the standard types, while in the latter, blocks of thirty or fifty single plants, from each sample, were planted out with the plants two feet apart in each direction, and each block alongside a control row of ten plants of the Aberystwyth S.48 strain.

RESULTS

Single Plants

Within three months after planting in the field, differences in plant type were apparent, and these became more distinct in subsequent months (Figs. 1–4) enabling periodic observations to be recorded on such features as relative growth at different periods of the year, leafiness or steminess of individual plants, stages of maturity, and susceptibility to frost damage (winter-burn). Generally, plants of

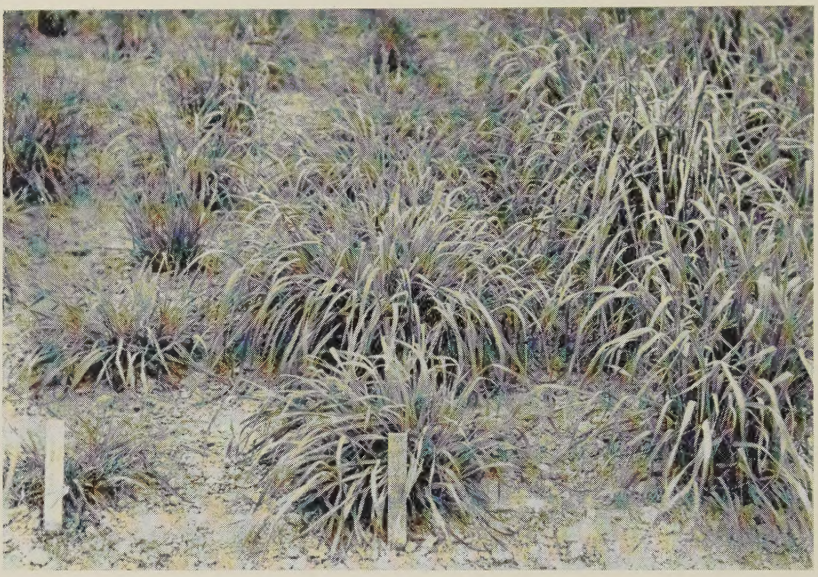

FIG. 2—Single plants. Summer growth 5 months after planting out.
Centre row: "Pasture hay" type control.
Remainder: Commercial hay types.
Photograph by L. W. Gorman.

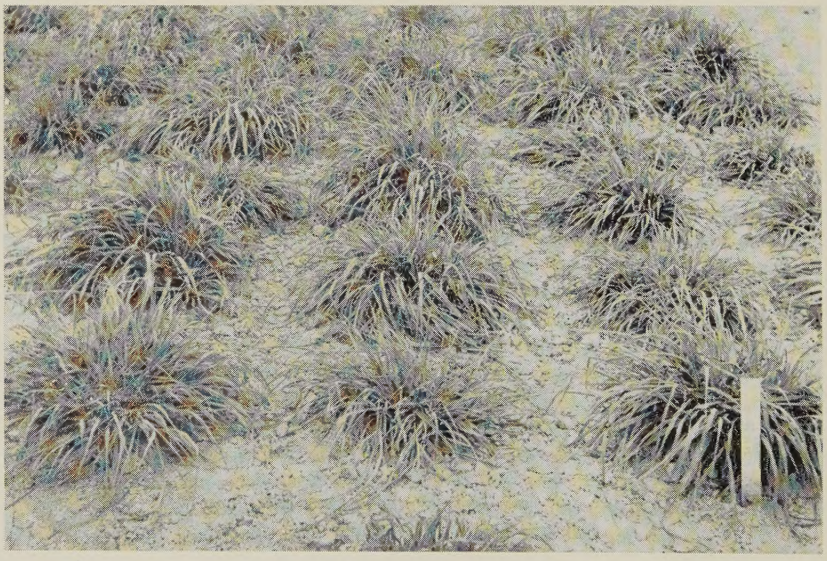

FIG. 3—Plants of "Pasture-hay" type. Note density and leafiness.
Photograph by L. W. Gorman.

the same origin were quite similar in type, but there were three major differing types briefly characterized as follows:—

1. Stemmy, tall growing and early flowering plants.
2. Leafy plants, later maturing and not so tall growing as 1.
3. Leafy, medium early flowering plants, prostrate growth habit.

In further reference Group 1 will be referred to as the "Hay" type, Group 2 as the "Pasture-hay" and Group 3 as the "Pasture" type.

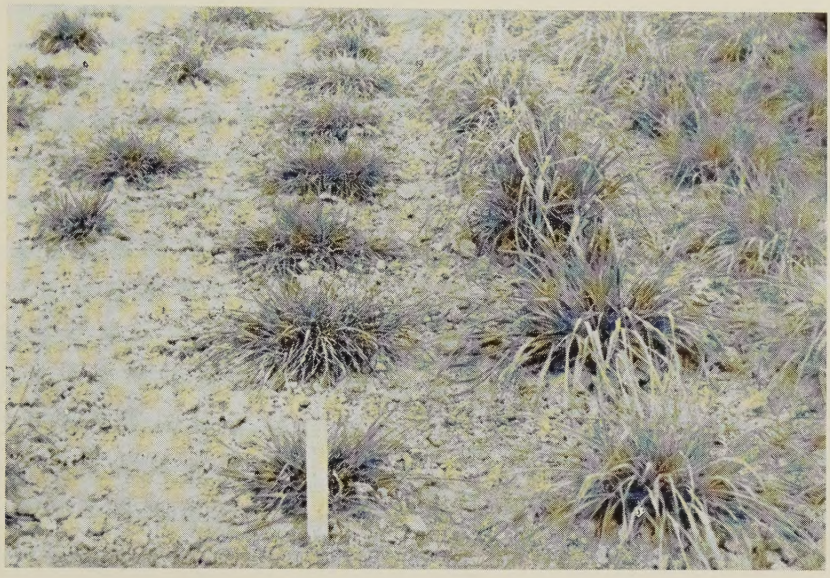

FIG. 4—Single plants. Left: "Pasture" type. Right: Welsh Plant Breeding Station's S.51 selection. *Photograph by L. W. Gorman.*

Observations on single plants in each of these groups are summarised in Table II.

Row Trials

Seedling rows of timothy established very slowly and often had to be grown on for six months before differences in type became apparent. With spring-grown plants the differences did not become pronounced until the late spring, approximately twelve months from the original sowing date. At this later stage the earlier flowering "Hay" types commenced sending up flowering shoots (Fig. 5), whereas the "Pasture-hay" type continued to make leaf growth and showed no emergence of flowering shoots for a further period of twenty-one to thirty days. The "Pasture" type (Fig. 6) remained quite distinct in that its growth was densely tillered, fine leaved and close to the ground, and its flowering shoots were relatively few in number. It was then possible to classify the different lines into one or other of the three groups already defined. In the course of these trials extending over several years, a close study has been made on 159 different samples and in Table III these have been arranged to show type in relation to origin.

TABLE III. TYPE IN RELATION TO ORIGIN

Origin	*Group Classification* "Hay"	"Pasture-hay"	"Pasture"
Commercial (origin unknown)	57	—	—
American	23	—	—
Canadian	3	—	—
Swedish	7	—	—
Scotch and English	6	—	—
New Zealand	28	2	—
New Zealand grown S.48 ..	—	8	—
New Zealand pedigree selections	—	9	—
Welsh P.B.S.	—	13	3
	—	—	—
Total (159 samples)	124	32	3

FIG. 5—Row trials. Left and right: Commercial "Hay" types. Centre: "Pasture-hay" type.

Photograph by L. W. Gorman.

FIG. 6—Row trials. Left: "Hay" type. Centre: "Pasture" type. Right: "Pasture-hay" type.

Photograph by L. W. Gorman.

In a recent trial the rows were grown on to a mature hay stage and then cut and weighed. Samples were taken for dry matter determinations and also for dissection into the components leaf and stem. The yield figures are given in Table IV below and although, in this trial, there was no significant difference between the yields of the "Hay"

TABLE II. SUMMARY OF OBSERVATIONS ON SINGLE PLANTS OVER A TWO YEAR PERIOD
(Figures Relative to Control at 100)

Group.	No. of Samples.	No. of Plants.	Relative Growth.					Winter Burn.		Percentage Early Flowering.
			First Year.			Second Year.		First Winter.	Second Winter.	
			Summer.	Autumn.	Winter.	Summer.	Winter.			
"Hay"	33	1,730	127	80	45	83	49	208	234	94
"Pasture-hay"	3	170	100	100	100	100	100	100	107	3
"Pasture"	1	50	50	67	90	67	60	Nil	Nil	85
Control ("Pasture-hay" type)	1	280	100	100	100	100	100	100	100	3
New Zealand Origin	8	400	150	117	83	100	60	100	134	92
Mixed Types	2	100	117	75	60	67	50	162	200	88

and the "Pasture-hay" types, the difference between the two types in ratio of leaf to stem was quite distinct.

TABLE IV. ROW TRIALS—HAY WEIGHTS

Group	No. of Samples	Average Yield Dry Matter in lb Per Row	Dry Matter Yield in Tons Per Acre	Ratio Leaf to Stem
"Hay"	7	2.76	4.1	1 : 5.11
"Pasture-hay"	9	2.75	4.1	1 : 2.23
"Pasture"	1	1.98	2.9	1 : 3.24
New Zealand grown	5	2.71	4.0	1 : 3.62

DISCUSSION

The quantity of timothy seed required for pasture sowings within New Zealand has been estimated to amount to 125 tons annually.[18] During the years 1937–43 there was an average annual importation of 107 tons, in 1944 there was no importation but in the following year 161 tons were imported from the United States of America. Since 1945 the production of New Zealand grown timothy seed has been expanded considerably with the result that no importations have been made in the years 1946–48. The sources of our imported seed, and the quantities imported anually during the period 1937–47, are shown in Table V. In those years 97 per cent of New Zealand's commercial supplies came from America.

TABLE V. IMPORTATIONS OF TIMOTHY SEED (IN CWT.) DURING THE YEARS 1937-1947

Country of Origin.	Quantity Imported (cwt.).										
	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
United Kingdom	15	—	2	—	—	—	—	—	—	—	—
Canada	200	—	—	187	—	—	—	—	—	—	—
Australia	—	—	—	—	—	36	—	—	—	—	—
Finland	100	—	—	—	—	—	—	—	—	—	—
Sweden	—	2	—	—	—	—	—	—	—	—	—
United States of America	2,058	2,531	2,301	3,531	180	1,117	2,790	—	3,214	—	—
Total (cwt.)	2,373	2,533	2,303	3,718	180	1,153	2,790	—	3,214	—	—

Origin of Trial Samples

Included in the twenty-three samples known to be of American origin (Table I) were the selections 1777 and 4059 from the Cornell Agricultural Experiment Station, and the "Huron" and "Marietta" selections from the Ohio Agricultural Experiment Station. The samples from Great Britain contained six commercial lots described as "Scotch" or "English", and sixteen samples from the Welsh Plant Breeding Station's selections. Other selections included in our trials were the Swedish Seed Association's "Gloria" and "Bottnia"; the Weibullsholm Plant Breeding Station's "Kampe I" and "Kampe II";

and the "Boon", "Milton" and "Montcalm" varieties as selections originating from the Canadian Experimental Farm at Ottawa and the MacDonald College at Quebec.

Forty-seven samples have been received as being New Zealand grown seed, seventeen of these representing nucleus and selected material. Of the remaining thirty, only fifteen could be traced back to the farms on which they were grown.

The commercial samples of unknown origin numbered fifty-seven.

Type in Relation to Origin

It is obvious from Table III that the majority of lines were of the "Hay" type. The only samples belonging to other groups were the Welsh Plant Breeding Station's selections, New Zealand selections of the "Pasture-hay" type and two New Zealand samples of natural origin. Within the "Hay" group were all the imported commercial samples as well as all the American, Canadian and Swedish selections.

The Canadian and American plant breeders have endeavoured to create regional strains to fit into a wide geographical range. A critical study of the relation of length of day to the growth of timothy plants[19 and 20] indicated that early maturing varieties growing in a short day could produce hay crops in the southern latitudes of the northern hemisphere, where the days during Spring and Summer were too short for full development of the late varieties. Conversely, the late varieties grew best in the northern latitudes. Nevertheless the differences in times of flowering of most of the Canadian and American selections included in our trials ranged over a period of only five to seven days, and although each selection was more leafy than the ordinary commercial type, in effect these selections characteristically belonged to the "Hay" group.

The Scandinavian countries which have a long and severe Winter and a relatively short growing season have favoured quick maturing types which are also winter-hardy under their northern climate. Under our conditions the plants of Swedish origin were semi-erect in growth habit, moderately leafy and, when fully grown, were not as tall as other "Hay" types. The times of flowering were the same as for other "Hay" types except in the "Bottnia" strain, which was slightly later.

Scotch and English commercial samples lacked uniformity in plant type. They consisted of a mixture of plants, some semi-prostrate and some semi-erect in growth habit. Some were leafy and others were more stemmy, but all were early flowering types.

The New Zealand samples of known origin were harvested in the Southland districts of Limehills, Boggy Burn, Winton and Otapiri, all within a circle of less than ten miles in diameter (Fig. 7) ; a further eleven samples, reputed to be New Zealand grown, were from seed lines on sale by southern seed merchants. The remaining few samples in this group were hand harvestings from timothy plants in different localities. As a group, the New Zealand samples were different in growth form from the average of the "Hay" or the "Pasture-hay" group. They were not as tall growing (Fig. 8) and were more leafy, less winter-dormant and better growing in the second year, and were seven to ten days later flowering than most plants of the "Hay" type. In two lines the plants were leafy and closely resembled plants of the "Pasture-hay" group except that they were earlier flowering.

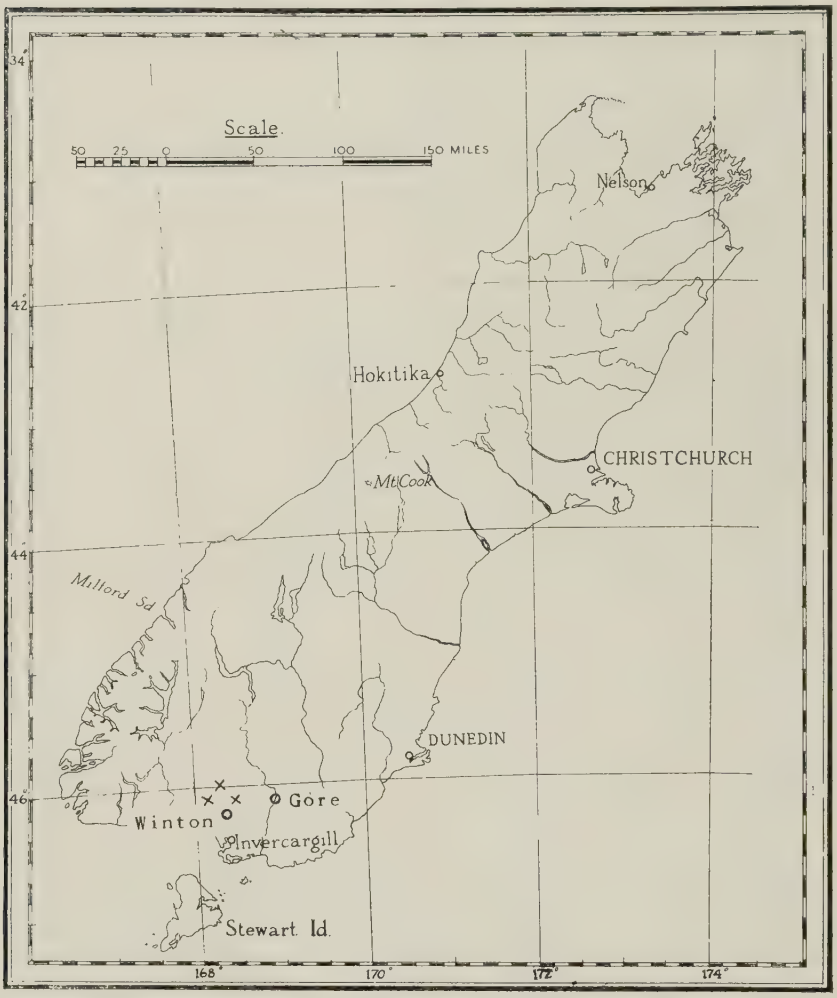

Fig. 7—Map of South Island of New Zealand showing districts in Southland in which a regional strain of timothy appears to have developed.

The Welsh Plant Breeding Station's selections S.48 ("Pasture-hay") and S.50 ("Pasture") have been built up from single plants collected as wild plants in English old pastures, and the S.51 ("Hay") selection has been derived from a single plant and its immediate progeny, grown from seed collected on uncultivated land in Wales.[21] Plants of the S.48 strain are very similar in colour to the commercial hay types except that they may be a slightly darker green. They are typically very late flowering, but they are also more winter green and tiller more profusely than the ordinary timothy. The flowering stems are not very tall, but under seed production and hay conditions they may produce good yields of hay of a leafy type. The individual plants spread rather widely at the base and develop a profusion of tillers. This strain is highly resistant to rust disease.

FIG. 8—Row trials. Left: "Pasture-hay" type. Centre: Southland grown. Right: Imported "Hay" type.
Photograph by L. W. Gorman.

The S.50 ("Pasture") strain differs essentially from other strains in that its chromosome number is different. It is a diploid ($2n = 14$), whereas the others are hexaploid ($6n = 42$), and therefore plants of S.50 do not readily intercross with ordinary types, although their time of flowering is concurrent with that of the American and Scotch timothy. Plants of this "Pasture" strain are very spreading in habit, and before flowering they form very dense, rather short-leaved, grassy cushions. The flowering stems are relatively short and the heads slender. During and after flowering, indeterminate, multi-noded, non-flowering tillers are produced; these trail close to the ground and frequently branch profusely. When these are trodden into the soil they root at the nodes and thus further plants arise by vegetative propagation.

Plants of the S.51 ("Hay") selection are light green in colour and have exceptionally long leaves. The flowering stems are not very stout nor very tall and as leafage comes high up the stems, it produces a particularly leafy hay. Plants recover well after cutting, and produce much more aftermath than ordinary timothy, and when not grazed too hard show considerable persistency. They are later flowering than ordinary timothy but earlier than S.48. In 1939 a small quantity (2cwt.) of the Welsh S.48 strain was imported and sown for seed production and seed from this area was distributed to other seed growers in Canterbury and in Southland. By 1945 there was sufficient evidence from our trials and from field experience to justify the inclusion in the New Zealand Government seed certification scheme of the progeny of this strain of timothy. Up till the 1947–48 season approximately thirty-six tons of "New Zealand grown S.48" seed had been harvested as certified seed.[22] This has provided the farmer

with an improved type of plant and made such available until a selection especially suited for New Zealand conditions, could be bred and marketed.

Hay Yields and Relative Leafiness

Although considerable importance has been placed on the growth of timothy for hay crops both in the Scandinavian countries and in the United States of America, it is interesting to note from Table IV that, under our conditions of soil and climate, the "Pasture-hay" type will produce as great a yield in terms of pounds of dry matter per acre as will the "Hay" type. Moreover, the former produces a hay of much better feeding quality in that it is twice as leafy as the latter. The hay from the extreme "Pasture" type is also leafy, but the total yield is relatively low.

Rust Resistance

In our trials no plants have been severely affected with rust, but overseas Research Stations have placed considerable importance on the breeding of selections resistant to attacks by stem rust (*Puccinia graminis phlei pratensis*). The inheritance of rust resistance has been determined at the Welsh Plant Breeding Station, and resistance has been found dominant over susceptibility.[23] It would therefore be possible in any timothy breeding programme to maintain or select further for rust resistance.

Frost Injury

The extreme "Pasture" type has not been affected by low temperatures and the "Pasture-hay" type has been only slightly damaged by frost, but plants of the "Hay" type have been considerably affected. The "Hay" group, as a whole, has been relatively susceptible to frost injury, but there have been differences in degree of susceptibility. The Swedish selections "Gloria", "Bottnia" and "Kampe II", which in Sweden are regarded as being high yielding, winter-hardy strains, exhibited no superiority in the trials but, on the contrary, were relatively low yielding and were the most susceptible to frost injury and consequent winter burning. Once these plants became browned off they went into a state of dormancy from which they recovered very slowly in the following Spring.

Plants of New Zealand origin were noticeably free from frost injury and continued to make some leaf growth during the first winter months; in the second year they were less vigorous and at that stage more susceptible to burning. However, they were never affected as severely as were plants from exotic lines of the "Hay" type.

Ecotypic Variation

Several references have been made to the ways in which a group of New Zealand grown samples differs from either the "Hay" or the "Pasture-hay" group. Although some timothy seed has been harvested in the Canterbury, Otago and Southland districts in previous years, samples from the Southland districts near Winton have been quite distinct in type, and readily distinguishable from other samples in our trials. In these latter districts the practice has been to establish almost pure stands of timothy (Fig. 9). A small percentage of white clover or red clover may be present, but the subsequent management allows strong growth of the grass which smothers the clover almost to extinction. Paddocks intended for seed production have been heavily stocked during the Winter months with either sheep or cattle, closed

FIG. 9—Field of "Pasture-hay" type (certified) closed for seed crop in October. Photographed late November.
Photograph by L. W. Gorman.

to stock by mid-October and at that time given a top-dressing of superphosphate and lime. The seed crop is generally ready for harvesting by mid-March, and after threshing is completed the paddocks are again ready for heavy stocking and the grazing animals then have access to the stacks of threshed straw.[24] In this way, by feeding the roughage back to the stock, soil fertility and productiveness have been maintained at a reasonably high level, and it has been possible to take as many as twenty-seven successive seed crops off the one area[22] and still obtain a good average yield of seed.

In past years approximately 50 tons of seed have been harvested annually from areas in Southland and handled by the southern merchants to build up a trade in Southland-grown timothy. As seed of the certified type is only just being introduced into Southland much of the seed used there for many years may have been locally grown seed. It would seem that the timothy seed originally introduced into Southland is likely to have been similar to that of the "Hay" types imported into New Zealand over the last fifty years, but in the trials carried out by the author plants from seed harvested within a well defined area in Southland have been found to be intermediate in many characters between those of the "Hay" and "Pasture-hay" types. Thus it would appear that intra-specific variation, due to ecological factors, has occurred in these districts since the original introductions were made, and a local or regional strain has been evolved.

CONCLUSIONS

Type Classification

The purpose of these trials has been to assess the value of available strains of timothy and to gather material for further improvement and selection. Although distinct phenotypic and genotypic differences

have been observed, each different sample has been classifiable into one or other of three groups as follows:—

Group 1, "Hay": Plants early maturing, stemmy, relatively few tillers, erect growth habit and tall growing; subject to frost injury, susceptible to rust disease and relatively winter dormant.

Group 2, "Pasture-hay": Plants late maturing, leafy, multi-tillered, semi-erect; flowering stems not as tall as in the "Hay" type; little frost injury, highly resistant to rust and capable of winter growth.

Group 3, "Pasture": A medium early maturing type, leafy, freely tillering, prostrate habit, short flowering stems; non-susceptible to frost injury, resistant to rust, capable of winter growth, persistent but slow growing and relatively low in production.

All the American, Canadian and European commercial samples included in the trials belonged to Group 1 and represented plant material which, in those countries, had been grown primarily for hay and for seed. Most of the earlier selections made by Plant Breeding Institutions in these countries have also been of the "Hay" type, but some more recent selections such as the Swedish "Kampe II" are later maturing and more like the grazing types.

English and Scottish commercial samples contained erect and semi-erect growing plants, all relatively early flowering, and thus classifiable as belonging to the "Hay" type.

Most of the New Zealand samples harvested prior to the introduction of certified timothy seed must also be regarded as belonging to the "Hay" group.

The Welsh Plant Breeding Station's selections provided most of the lines classified into Groups 2 and 3. Both the S.48 and S.51 strains have been included in the "Pasture-hay" group.

The S.48 selection has proved persistent under heavy grazing, especially on the heavier and relatively fertile soils. The S.51 selection was less tolerant of hard grazing.

The only lines in the "Pasture" group were three samples of the Welsh strain S.50, and the plants of these were morphologically quite distinct from all other timothy plants.

Usefulness of Types in New Zealand

The commercial hay types which have dominated the New Zealand seed market in previous years have not given the farmer the type of timothy he really required. Most of the seed was required for inclusion in mixtures for sowing down long term pastures which were liable to be closely and continuously grazed by sheep. Under this type of management the "Hay" types produced little herbage, and often rapidly disappeared from the pasture.

Undoubtedly the "Pasture-hay" type is the one which should be of the greatest use to the New Zealand pastoralist. Its ability to tiller and make dense leafy growth, its resistance to rust and winter burn, and the fact that it will produce a good hay crop, or will persist under heavy grazing, make it a most valuable type for use in this country.

The extreme "Pasture" type (Group 3) may have a place in New Zealand, but in all trials to date it has made insufficient growth to warrant its inclusion in places where timothy is normally grown. Its stoloniferous tendencies and frost resistance are important characters which would be useful in a plant improvement programme, but as the only plants available in this group are diploids there would be

technical difficulties in transmitting these characters to other plants of the hexaploid type.

General

The extension of the New Zealand Seed Certification scheme to include timothy seed of the "Pasture-hay" type has ensured that the identity of this particular type will be retained, and that seed genuinely of this type will be available to all prospective users of timothy seed in this country.

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CONGENITAL PHOTOSENSITIVITY IN SOUTHDOWN SHEEP

A NEW SUB-LETHAL FACTOR IN SHEEP

By John Hancock, Ruakura Animal Research Station,
Department of Agriculture, Hamilton

Summary

(1) The aetiology of congenital photosensitivity and the clinical symptoms of lambs affected with the disease are described.

(2) Conclusive evidence based on planned breeding experiments shows that this disease depends on a single recessive factor with full penetrance. This factor has been called "p". Lambs affected by this disease invariably die if kept under normal outdoor conditions. The factor "p" may be classed as a sub-lethal.

(3) The distribution of the gene p in the Southdown sheep population of New Zealand is discussed.

(4) To decrease the frequency of the factor p the following measures seem practicable: (a) avoidance of breeding from heterozygotes; (b) outcrossing to untainted strains; (c) uncovering of heterozygous animals by test mating. The last-mentioned measure is only recommended in the case of rams which are likely to be of very great importance to the breed.

(5) The role of the Southdown Breed Society in any eradication programme which might be undertaken has been indicated.

Introduction

In the course of investigations which followed the extensive outbreak of so-called "facial eczema" in sheep in 1935 and 1938 in New Zealand, some attention was directed towards diseases of an allied nature. One of these was congenital photosensitivity in Southdown sheep of which a brief description has been given by Cunningham *et al.*[1] This condition was first noted by Leslie,[2] who described an outbreak in the flock of the Lincoln Agricultural College. As the result of a few test matings, Hopkirk, according to Cunningham,[3] postulated that this disease was probably inherited and its expression depended on recessive factors.

In view of the great importance of the Southdown rams as the premier fat lamb sires in New Zealand, any suspected inherited defects present in this breed warrant the closest attention of research workers and breeders alike. Work was commenced by the Animal Research Division of the Department of Agriculture in 1940. The genetical aspects were studied at the Ruakura Animal Research Station, and the aetiology of the disease at Wallaceville Animal Research Station. Clare[4] has shown that the condition is a true photosensitive disease, in which phylloerythrin derived from chlorophyll in the diet is the photosensitizing agent.

In the present paper, the clinical picture of congenital photosensitivity is described, and the results presented from breeding experiments planned to test the theory that the disease depended on inherited factors. It is obvious that until these questions were answered, no intelligent action aiming at the eradication of the disease from New Zealand flocks could be attempted.

Clinical Symptoms

A lamb born with congenital photosensitivity is apparently normal at birth. Visible symptoms first appear at approximately the age at which the lamb begins to eat grass, i.e. when it is five to seven weeks

old. The exact time, however, is not easy to ascertain as onset is not very sudden and depends on a number of factors which vary from lamb to lamb. Such factors appear to be the milking ability of the dam with its resultant effects on grass intake of the lamb, and the intensity of light to which the lamb is exposed.

The course of the disease runs parallel with that of facial eczema,[1] with the difference that no spontaneous recovery occurs. Figures 1, 2 and 3 show a lamb in advanced stage of the disease. The affected parts often become so infected that the ears slough and the eyes are destroyed. If affected lambs are left out of doors they invariably die two to three weeks after the appearance of first symptoms. The immediate cause of death is sheer exhaustion as a consequence of starvation. If the animals are brought into permanent shelter from the sun at an early stage they grow approximately at normal rate. A number of such animals have been kept to maturity at Ruakura and are capable of breeding and reproducing normally. After a short time the doors to their shed can be left open day and night, as the lambs are soon conditioned to graze only during the night and to seek the shelter as soon as sunlight becomes intense. Under these circumstances they do not show any outward signs of photosensitivity.

Clare[4] has shown that the primary cause of congenital photosensitivity in Southdowns is the inefficiency of the liver of an affected animal to excrete phylloerythrin. Quite remarkably, no macroscopic or microscopic changes such as are always present in facial eczema can be demonstrated in the liver. Liver dysfunction can be detected by the Rose Bengal liver-function test, long before the lambs become photosensitive. When this test (as applied to sheep by Shaw[5]), was used on very young lambs, it was found that excessive haemolysis invariably interfered with colorimetric readings. This was overcome

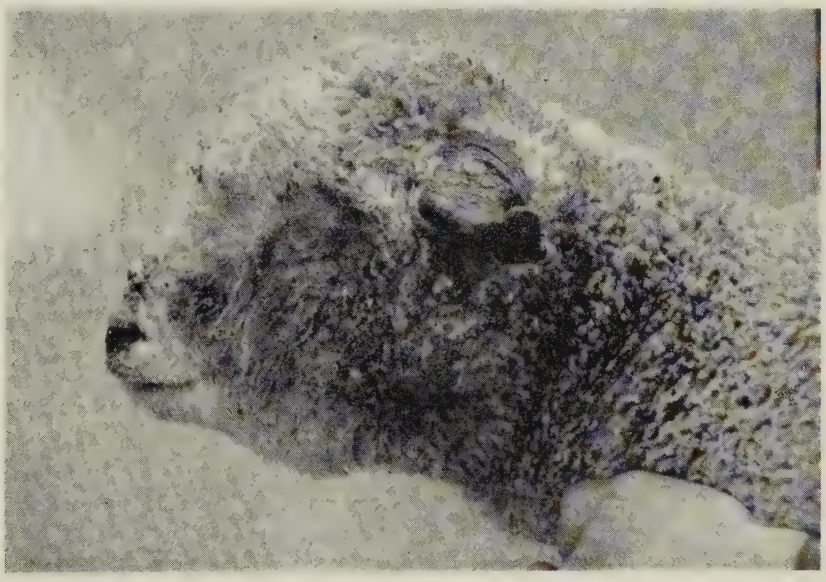


FIG. 1

FIG. 2

FIG. 3

partly by decreasing the amount of injected dye solution to 1 ml and partly by clearing the serum with equal amounts of acetone followed by centrifuging. Affected lambs have a very low liver efficiency measured by this test, only 3–15 per cent of the dye being excreted, whereas apparently normal mothers of such lambs show a normal excretion rate of 65–85 per cent. Five lambs which remained normal showed an excretion rate of 65–75 per cent. As Clare[4] has shown, there is a retention of bilirubin to the extent of 0·1–1·0 mg/100 ml. The

Van den Bergh test is, however, not very useful in detection of affected lambs prior to photosensitivity, in that retention of bile pigments on this level can be caused by various other conditions.

GENETICAL ASPECTS

To initiate breeding work, a ram (599) and a number of ewes were obtained by Dr F. W. Dry, of Massey Agricultural College, from a flock (A). According to the evidence of the breeder, several photosensitive lambs had been born in this flock in many previous years. The ram and three of the ewes showed signs of having suffered from photosensitivity at an earlier age, but they remained normal throughout the time they were under observation at Ruakura. It must be remembered that at this stage the aetiology of the disease had not been fully investigated. Thus, for instance, it was not known whether some animals under normal circumstances might not recover. As a working hypothesis, it was therefore assumed that the Ram 599 and the three above-mentioned ewes were true cases of congenital photosensitivity.

A number of ewes from the Ruakura Stud Southdown flock were added to the experimental flock in 1940 and again in 1941. No cases of the disease had ever been reported in the Ruakura flock. In 1941, an additional five ewes were obtained from another flock (B). Sires bred in this flock had been used for several years in Flock A. One of these latter ewes had lost her ears, apparently the result of photosensitivity.

Ram 599 was mated for two seasons to all these ewes with the progeny results as set out in the following table:—

TABLE I. CONDITION OF PROGENY FROM EWES TESTED

Origin of Ewes	Condition of Progeny			
	Photosensitive	Doubtful	Normal	Total
Flock A	2	1	13	16
Flock B	–	–	5	5
Ruakura	2	3	20	25
	4	4	38	46

In the light of present knowledge it is safe to assume that all eight lambs classed as photosensitive or doubtful were cases of facial eczema. The evidence for this is twofold.

(1) They became photosensitive late in life, during the months of February and March, the period when facial eczema is prevalent;

(2) On autopsy the liver showed lesions indicative of this disease. Only one of these animals survived. After becoming affected, it was housed in a dark shed throughout the autumn and the following winter. In the spring it was let out and suffered no ill-effects from the sunlight. It can thus be concluded that this also was a case of facial eczema.

Fortunately, Ram 599 died in 1941 and showed upon post mortem examination liver changes typical of facial eczema. It was now essential to obtain new breeding material and Dry was able to secure in the spring of 1941 from Flock C, in North Auckland, eight apparently normal ewes suckling photosensitive lambs; in addition, two rams, one or both of which had sired these lambs, were obtained. Only five of the lambs arrived at Ruakura and two of them died almost immediately. The remaining three, one ram lamb and two ewes, were held

in a darkened shed until the following spring, when they were let out. After a few minutes in the sunlight they showed unmistakable signs of photosensitivity and were brought back into the shed. Their reaction to the sunlight was thus altogether different from that of the photosensitive lambs bred at Ruakura the previous year, and from that of ewes that had recovered from facial eczema.

In the 1943 mating season all available Southdown ewes were divided into two flocks on an equal breeding basis and mated to Rams 448 and 449 from Flock C. In the following spring five lambs were born which showed photosensitivity when they were five to seven weeks old. These animals were by one ram (448) and all but one were out of ewes from Flock C. This animal was out of one of the ewes from Flock B.

These results established experimentally that apparently normal parents could produce affected progeny. Such a situation strongly suggested that the condition was due to the action of recessive factors and future breeding programmes aimed at testing this possibility.

A photosensitive ram which was obtained from the Wallaceville Animal Research Station and a ram originally obtained as a lamb from Flock C together with Ram 448 were used in the 1944 season. For the following two years (1945–6) it was possible to concentrate on the use of affected rams only. These were back-crossed to daughters by such rams and out of presumed non-carrier ewes.

Table II summarizes the results of all breeding operations, after the aetiology of the disease had finally been determined. The following assumptions have been made:

(1) Sheep which had become photosensitive when a few weeks old and remained so throughout their lives have the gene formula pp;

(2) Unaffected progeny of one affected parent, together with animals which, although not affected themselves, have produced such progeny, have the formula Pp; and

(3) Sheep from flocks in which affected animals never have been born have the formula PP.

TABLE II

Type of Matings	Observed Ratio		Expected Ratio	
	Affected	Unaffected	Affected	Unaffected
pp × pp	14	0	14	0
pp × PP	0	74	0	74
pp × Pp	16	18	17	17
pp × (Pp × PP)	5	17	5½	16½

Other affected lambs have been born, but they cannot be fitted into a Mendelian ratio as they have been progeny of rams with the gene formula Pp mated to a sample of ewes in which the proportion of Pp to PP individuals was not known.

It is immediately apparent that there is excellent agreement between the observed and expected ratios. On this basis it can be stated that the expression of the disease of congenital photosensitivity in Southdowns depends on a simple recessive factor with full penetrance.

Some of the ewes in the matings of the type pp × PP were of Romney breed. When the ewe progeny of these matings were back-crossed to pp rams, three out of six lambs born were affected. There is thus good evidence that one-quarter-bred Romneys do not carry factors inhibiting the expression of the photosensitive gene. [Since Southdown and Romney ewe lambs are seldom retained for breeding, the dangers inherent in this situation are not very real.]

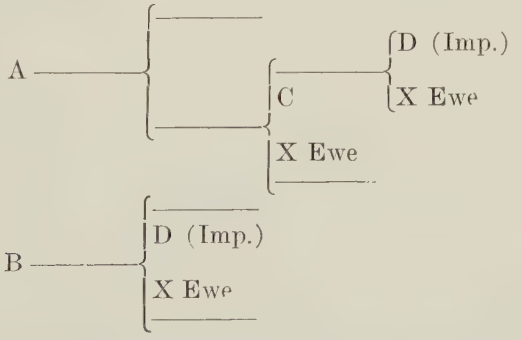
The frequency of the factor p in Southdown sheep in New Zealand is very difficult to ascertain, but there are indications that the factor may be fairly widely spread, as the following discussion will bear out.

In the random bred population, lethal factors tend to be self-restricting in that animals which are homozygotes for the factor are automatically non-reproductive. The elimination of all known heterozygotes would in addition bring about a rapid decrease in incidence of homozygotes as to make the number of such animals born economically unimportant. However, the Southdown breed in New Zealand is not a random bred population. Stevens[6] has shown that the Southdown flocks in this country can be divided into two categories:

(a) The "nucleus" flocks in which a relatively great proportion of the ram lambs are "single" entered in the Southdown Stud Book. These rams are mainly used in

(b) the "propagating" flocks for the purpose of producing sires for the fat-lamb industry.

The sires used in the "nucleus" flocks are mainly either imported from England or are sons of imported animals. As the "nucleus" flocks themselves, representing only seven per cent of all Southdown flocks in New Zealand, obtain their rams from a restricted number (three main flocks) of fashionable flocks in England, it is clear that a considerable amount of close breeding must take place. This applies also to the "propagating" flocks, as the owners of these often buy their rams from the same breeder year by year. In a population with a structure such as this, detrimental recessive genes would be widely spread if introduced by animals which, because of their fashionable breeding, or actual merit, gain great popularity. This seems to have occurred with the gene p in New Zealand Southdowns and the following well-authenticated cases may be cited as an example. An owner of a flock of category (b) reported that in one season twelve photosensitive lambs were born in his flock out of approximately 125 ewes. The sire (A) and the maternal grandsire (B) of these lambs had been bought from a well-known flock (X). Their respective pedigrees were as follows:—



As far as can be ascertained, the only animal common in both pedigrees is the imported ram (D) and it may, therefore, be assumed that this ram carried the factor p. It must, however, be pointed out that it is not possible to follow the maternal lines, as ewes are only very occasionally "single" entered in the Stud Book. Further evidence, indicating that Ram D was a carrier, comes from the fact that another

ram imported from the same flock in England and bred on similar lines to Ram D has also been incriminated as a carrier as judged by the breeding performances of two of his sons when they were mated to their own daughters and nieces.

If the assumption that Ram D was a carrier is correct, it is possible to estimate the spread of the factor p due to this ram, and to his son C, which also must have carried the factor. A search of the flock books shows that during the eleven years these two rams were used in Flock X, 41 probable "carrier" rams had been transferred to other breeders. This number was made up as follows:

	Total No. Transferred	Probable No. of Carriers
Sons by D	49	24
Sons out of daughters by D	17	4
Sons by C	20	10
Sons out of daughters by C	13	3
	99	41

At present, a fair proportion of the ewes in the "nucleus" Flock X must carry the factor and will in their turn further spread the condition to other flocks through their sons.

This is only one instance of the extent to which a single animal may have spread this undesirable gene. Because the flock from which Ram D was imported is a very fashionable breed, it is likely that further importation from the same stud will take place in the future, with the consequent risk of new introductions of the factor p. In view of this position it is, therefore, probable that cases of photosensitivity in Southdowns will continue to occur as frequently as previously and possibly at an increasing rate, thus causing appreciable economic loss to Southdown breeders.

POSSIBLE MEANS OF REDUCING THE INCIDENCE OF CONGENITAL PHOTOSENSITIVITY

Technically it would be possible to eradicate completely the gene p from Southdown flocks in New Zealand. The ensuing economic gain would hardly cover the cost of such a procedure which would involve rigorous test matings for several generations. However, various methods of reducing the incidence of affected lambs may be considered.

(1) *The Elimination of Proved Heterozygotes*

This could be accomplished by de-registration or slaughter of all rams and ewes which have produced affected offspring. Unaffected lambs by heterozygotes could still be sold as fat lamb sires, though castration would obviously be the safer policy. Such a programme alone would cause a rapid fall in the frequency of the gene p, and consequently the number of affected lambs born would become negligible.

(2) *Outcrossing as a System of Mating*

As inbreeding increases homozygocity of all characters, this system of mating should be avoided in Southdown strains in which photosensitive lambs have appeared. A successful outcross would lower the frequency of the undesirable gene to such an extent that a return, if necessary, to the original stock could be undertaken, with the knowledge that few if any affected lambs would be born. Though no guarantee can be given that an outcross ram would be a non-carrier

of the p gene, this course represents the safest procedure open to the small multiplier of commercial type of Southdown rams. This is more likely if the animals are from a stud where the disease has not existed. At the same time it must be emphasized that in view of the mode of inheritance of this defect, no flock can be judged absolutely safe. All the leading flocks are interrelated and the spreading of the gene is likely to be almost universal.

(3) *The Uncovering and Elimination of Heterozygous Rams by Systems of Test-mating*

As a ram probably leaves thirty to forty times more progeny than a ewe, it is realized that if at least a proportion of all heterozygous rams could be eliminated from further breeding work, a rapid decline in gene frequency would result. This aim could be accomplished by test-mating rams prior to extensive use. The following three systems of test-mating are practicable:

(a) Back crossing a ram to his own daughters;

(b) Mating a ram to the offspring of heterozygous ram or heterozygous ewes;

(c) Mating a ram to the progeny of a homozygous ram.

The first system could be used by any breeder, and is, therefore, the one which is of greatest practical consequence. The second system could be used by breeders who have had the misfortune of having previously used heterozygous rams. To make the third system possible the maintenance of a test flock is necessary. It must be pointed out that any test-mating plan would be expensive and, therefore, unpopular with breeders if they were forced to do the work themselves. This becomes clear when it is realized that, as has been discussed by Korkman,[7] twenty to sixty matings resulting in no affected offspring are necessary in order to declare a sire free from a recessive factor. However, the responsibility of the Breed Society and the individual breeder in the matter is clear. Serious consideration of practical measures to eliminate this defect in the breed should be given at an early date. Elimination is not beyond the bounds of practical possibilities in view of the nucleus structure of the Southdown breeding industry.

Any constructive attack aimed at decreasing the incidence of affected lambs is hampered by two factors:

(1) Ignorance of the fact that the disease is inherited; and

(2) A tendency on the part of many breeders to conceal the evidence of affected lambs in their flocks.

The obvious remedy for these shortcomings is a vigorous publicity and educational campaign. This again is a task partly for the extension service of the Department of Agriculture, and partly for the Southdown Breed Society. It is felt that little can be done without the wholehearted co-operation of the Breed Society. Constructive measures such as, for instance, de-registration of known heterozygotes must of necessity originate from the breeders themselves. Although such an action may be economically detrimental to a few individual

breeders, it would benefit the great majority, and thus fall well within the scope of the Society's main activity, which is to protect and further the interests of all its members, and to maintain the high standard of efficiency of the breed for which it is responsible.

Acknowledgments

Due to the impact of war conditions upon personnel this project has had a somewhat chequered history. In the absence of a Geneticist at the commencement of the work at Ruakura, Dr F. W. Dry, of the Massey Agricultural College, contributed advice in planning and practical aid in locating suitable breeding material. The author is very grateful to him for this assistance. Control of the breeding flock was in the hands of Mr I. Watt, Veterinary Research Officer, whose assistance with this project was terminated after one and a half years by war service. Responsibility was then assumed by the author, who retained full control except for one mating and lambing season (1944–5) when the breeding work was supervised during his absence overseas by Mrs E. Bassett, to whom thanks are also due. The author is also grateful to Mr W. Metcalf for devising the modification of the Rose Bengal test so that it could be applied to lambs.

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SOME RESULTS ON THE ACCURACY OF MILK SAMPLING OVER A COMPLETE LACTATION AND THE DAILY VARIABILITY IN MILK YIELDS

By I. D. DICK, Applied Mathematics Laboratory, Wellington

Summary

Results are given as to the accuracy of sampling a lactation yield at various sampling intervals. Data are also given on the day to day variability of milk yield.

INTRODUCTION

ALTHOUGH the accuracy of milk sampling over a complete lactation has been extensively studied overseas (for representative publications in this field, see ref.[1], there is, to the best of the author's knowledge only one publication wherein this problem has been studied for New Zealand conditions. This study[2] was undertaken by I. L. Campbell to investigate the accuracy of current New Zealand herd-testing practices. It was later suggested by the Dairy Research Institute that the scope of Campbell's work be extended.

The method of sampling and the computations used by Campbell to calculate the lactation production were those used by the different herd-testing authorities. In this paper a systematic sample was used throughout. The sample was taken in the following way: A sampling period of n days having been chosen, the sample was taken every nth day after calving. The average daily production of the sample total was taken as the average daily yield of the cow over its complete lactation. The lactation production was then obtained by multiplying this average by the total number of days the particular cow was in milk.

This method of sampling was used because of the ease with which the work could be done on punched card machines, using a technique developed by J. H. Darwin and E. W. Jones.

EXPERIMENTAL

The material used in this study consisted of the complete daily milk yields of 52 cows, mostly Jersey or Jersey-Ayrshire cross, in the Dairy Research Institute herd in the 1939–40 and 1940–41 seasons.

RESULTS AND DISCUSSION

The major results are listed in Table I and shown graphically in Fig. 1.

Table I

Period	Average Percentage Error	Absolute Average Error	Standard Deviation of Percentage Error
2	0.054	0.44	0.37
3	0.17	0.56	0.49
4	0.032	0.71	0.61
6	0.36	1.01	0.69
7	−.07	1.18	0.98
8	0.14	1.14	0.84
9	0.31	1.10	0.75
12	0.014	1.50	1.02
14	−.11	1.45	1.20
21	0.044	2.09	1.77
24	−.87	2.62	1.97
28	−.55	2.85	2.39

Table I shows that bias in the sampling results may be safely neglected for all periods as the highest average percentage error does not exceed one per cent. Fig. 1 shows that the relationship between the sampling period and the standard deviation of the percentage error follows a straight line law very closely. These findings agree with those of McCarthy and Boyle[3].

It is also worth noting that, as McCarthy and Boyle also report, no correlation between the percentage error and either the daily milk or total lactation production was found.

On page 38 of ref.[1] papers are mentioned which claim that the accuracy of sampling depends not only on the period used but also on the point within the period at which the sample is taken. As explained earlier, the results here were obtained in all cases from samples taken on the last day of the period under study. This point was examined in detail for periods of 7 and 28 days. In Table II, listing the results for the 7-day period, the first column (starting point) shows on which of the 7 days of the sampling period the sample was taken.

Table II

Starting Point	Average Percentage Error	Absolute Average Error	Standard Deviation of Percentage Error
1	−.07	1.18	0.98
2	−.07	1.14	0.80
3	0.16	1.11	0.81
4	0.18	1.01	0.87
5	−.12	0.82	0.60
6	−.07	1.06	0.83
7	0.02	1.05	0.74

Table III

Starting Point	Average Percentage Error	Absolute Average Error	Standard Deviation of Percentage Error
4	−.38	2.36	1.55
8	−.13	3.00	2.14
12	0.13	2.28	1.78
16	1.00	2.69	2.49
20	0.24	2.48	2.10
24	0.54	2.67	1.77
28	−.56	2.84	2.42

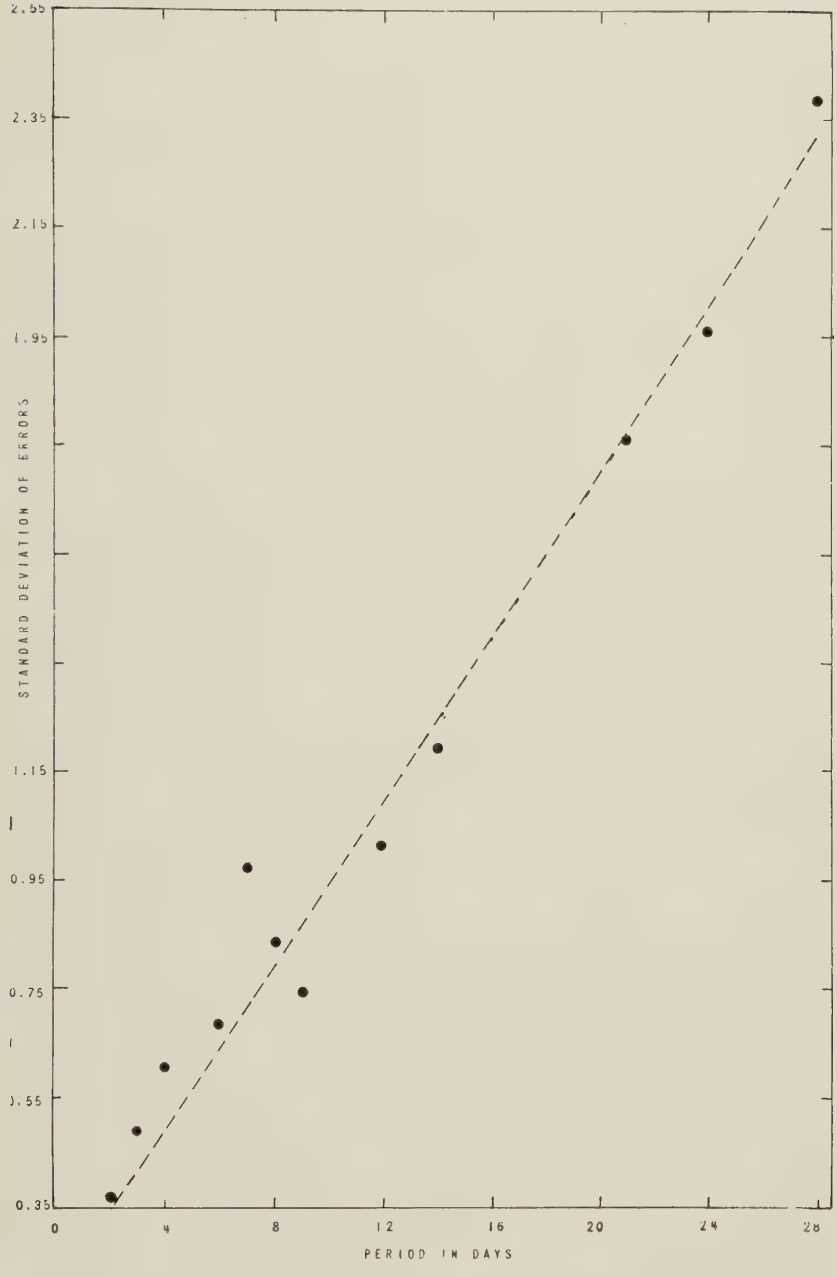
2.55
2.35
2.15
1.95
STANDARD DEVIATION OF ERRORS
1.15
0.95
0.75
0.55
0.35
0
4
8
12
16
20
24
28
PERIOD IN DAYS

FIG. 1

Table III shows the results for the 28-day period. In this period only seven different starting points were examined.

Using Bartlett's test for the homogeneity of variances, it was found that for each period there were no significant differences between the standard deviations of the percentage errors obtained by using different starting points. For the 14-day period, Table IV lists the average percentage error only for each starting point. In light of the results found for the 7-day and 28-day periods, further work on the 14-day period seemed superfluous.

Table IV

Starting Point	Average Percentage Error	Starting Point	Average Percentage Error
1	–.11	8	–.03
2	–.58	9	–.45
3	0.09	10	0.30
4	–.14	11	0.42
5	–.25	12	0.04
6	–.06	13	–.01
7	0.16	14	–.11

The daily variability in milk yield will now be considered. Besides its own intrinsic interest, the daily variability has a certain significance for various aspects of herd-testing procedure, especially check-testing. To calculate the variability, the following assumptions were made:—

(1) That each cow possesses its own smooth lactation curve which, if the environment remained constant from day to day, would determine the successive daily milk-yields. The actual milk-yields are, however, the sum of the yield expected from this smooth curve, plus a random term, the size of which is determined by the peculiarities of each successive day.

(2) That this random term came from a normal population with zero mean and standard deviation, v. The standard deviation, v, is what, in this paper, is meant by the variability.

Having thus defined the variability, the next problem is to estimate it from actual data. Initially, either of two methods appeared suitable—to use the variate difference method or the residual variation after the actual lactation figures had been fitted by, say, a third degree polynomial. Both methods were tried and finally the variate difference method used because (1) it was nearly always found that to secure a reasonably good fit to the lactation curve, a third-degree polynomial was required and occasionally even one of the fourth degree, and (2) the variate-difference method required much less computational labour.

The essence of the variate difference method is to form the differences of successive daily milk-yields. The sum of squares of these successive differences equals approximately $2(n-1)v^2$, where n is the number of days the cow was in milk. Following the normal variate difference technique,[4] it might be thought that higher order differences would yield a smaller or more reliable estimate. Consequently,

v was calculated for six cows using both the first and second differences. The results were as follows:—

Cow No.	V_1	V_2	Cow No.	V_1	V_2	Cow No.	V_1	V_2
1	2.70	2.59	3	2.08	2.12	5	1.88	1.90
2	1.88	1.96	4	1.46	1.45	6	2.22	2.22

The close agreement between V_1 and V_2, the variabilities estimated from the first and second differences respectively, indicated that first order differences would be sufficient.

The absolute and percentage daily variabilities of the cows used for the sampling investigation were calculated. For the fifty-two cows in the group the mean and standard deviation of the absolute variability were 2·02 and 0·645 lb of milk respectively; for the percentage variability the corresponding figures were 8·13 per cent and 2·65 lb.

The correlation between the absolute variability and average daily production was 0.45; between percentage variability and average daily production, zero.

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THE INFLUENCE OF SEX UPON CARCASS QUALITY OF NEW ZEALAND FAT LAMB

By D. E. Walker, Ruakura Animal Research Station, Department of Agriculture, Hamilton

Summary

(1) The effect of sex on the live weight growth, carcass weight, dressing percentage, carcass measurements and grading of Southdown-Romney Cross fat lambs under varying seasonal conditions is discussed.

(2) Ram lambs are heavier (live weight and carcass weight) than wether lambs and wether lambs are heavier than ewe lambs. Dressing out percentages are in the reverse order.

(3) In all carcass measurements the ram lambs exceed the wethers and the wethers the ewes, even when due correction for weight has been made. On the whole, conformation of the ram lambs is better than that of the wethers, and that of the wethers is better than that of the ewes.

(4) The grading system penalizes ram lambs as having insufficient fat cover and being too "coarse". Grading standards in relation to market requirements are discussed.

(5) In spite of grading discrimination, highest financial returns are shown for ram lambs, the amount varying according to the type of season experienced. The possibility of a penalty being exacted by all freezing companies for slaughtering ram lambs must not be overlooked.

(6) Data show that sex influences are sufficiently strong to warrant consideration of this factor in the planning of experimental work.

(7) A non-castration policy over two-thirds of the male lambs in New Zealand is estimated to increase the weight of meat by some 1,000 tons annually. This conclusion is of considerable significance under present conditions of world food shortages.

Introduction

The influence of sex upon form, structure and behaviour of the farm animal has long been recognized. Major differences between males, females and castrates are a matter of everyday observation. In particular, the so-called secondary sex characters give rise to obvious variations in body proportions. Such differences markedly affect usefulness for meat purposes.

Many workers have recorded observations on some of the effects of sex upon various characters of sheep, cattle, pigs and fowls, and their conclusions testify to its modifying influence upon carcass quality. The accepted policy of castrating males intended for slaughter is a measure of the importance attached to sex effects by the farmer. Spaying of females, being a more difficult operation, is less frequently practised, though farmers are well aware of its capacity to improve the female intended for fattening. Most available data, however, are derived from projects designed primarily for other purposes and are limited in consequence to comparisons of castrate males and entire females, these being the sexes of greatest economic importance. Only on pigs has a more complete study been made. Thus Murray[1] dealt with entire and castrate animals of each sex. His data, however, are restricted to linear body measurements and are open to the criticism that sex effects were confused with the influence of weight of animal. Wallace,[2] also using the bacon pig, in an investigation designed to elucidate the detailed pattern of differences in body structure due to sex, and the effect of sex on food

utilization, gives a comprehensive picture of the effect of sex on carcass quality and composition, rate of growth, and efficiency of food utilization. He found the superiority of the entire male to be outstanding in all these characters and, under present-day conditions, questions the adherence to the practice of castration for male pigs intended for fattening where pigs for both pork and bacon are slaughtered at such an early age and before sexual maturity has been reached. From a study of body form in swine, Comstock and Winters[3] decided that the testes accelerated rate of gain up to puberty. Similarly Hunt *et al.*[4] found that ram lambs were heavier at five months (the normal age of slaughter) than wethers, although the latter had the higher dressing out percentage. Ostertag[5] has stated that a young male bull utilizes food better and puts on more meat than the castrated animal with access to the same quantity of feed, and is thus ready for slaughter at an earlier age. The meat can be produced more cheaply in the case of a young bull than a steer and there is a quicker turnover in slaughter cattle, which leads to a big increase in meat production and also meets today's requirements of taste which prefers muscle to fat.

As regards composition, it is a matter of common observation, confirmed by experimental work, that removal of the sex glands is followed by an increased rate of deposition of fat in the body. Hammond[6] states that wethers carry a higher proportion of fat and rams higher proportions of muscle and bone, and suggests that the practice of castrating lambs intended for the fat lamb trade is open to investigation in view of the demand for lean meat. Although Hammond made some fundamental contributions to growth studies and reached some "tentative" conclusions, the scope of his work was limited by the scanty nature of the material employed. There is, on the whole, a lack of factual information regarding sex and carcass quality in sheep. Since one of the objectives of this Station is a critical examination of meat production in New Zealand and the factors affecting its efficiency, the following investigation of the relationship of sex to fat lamb production has been undertaken.

Material and Procedure

Lambs used in this investigation were Southdown × Romney, the most important fat lamb cross in the North Island. The material falls into three main groups:—

(a) A flock reared at Ruakura Animal Research Station in 1944–5.

(b) A flock at Mamaku Experimental Farm in 1945–6.

(c) A flock at Ruakura Animal Research Station in 1945–6.

Owing to the different weather conditions obtaining, these flocks may be considered to have been reared under good, fair and poor seasonal conditions respectively.

In the preliminary experiment at Ruakura the male lambs were divided into two groups by eye at docking time, alternate lambs of approximately equal size being allotted to either group. These lambs were weighed ten days after docking, but it was not possible to get further live weights.

In the following year, both at Ruakura and at Mamaku, all lambs were weighed immediately prior to docking and the male lambs allotted to their group on a restricted random basis. No ewe lambs were available at Ruakura in this season. The Mamaku lambs were weighed again prior to slaughter. Docking and castrating was done by knife in all groups. Lambs were picked as "fats" by a buyer in the normal manner.

After slaughter, carcass measurements,[7, 8] weights, and grades were taken for all lambs.

RESULTS

Weight Data

The number of animals in each group and the relevant weight data are given in Table I.

TABLE I. MEAN WEIGHT DATA

Group	No.	Docking Wt. (lb)	Slaughter Wt. (lb)	Carcass Wt. (lb)	Dressing Out %
Ruakura 1944–5					
Rams	53	33.0†	—	39.8±0.653	
Wethers	50	33.3†	—	38.2±0.551	
Ewes	78	30.9†	—	36.3±0.486	
Mamaku 1945–6					
Rams	116	23.3	76.5*	34.6±0.438	45.23
Wethers	105	23.3	71.2*	33.6±0.458	47.19
Ewes	208	20.9	64.9*	31.5±0.254	48.54
Ruakura 1945–6					
Rams	111	21.9	—	32.6±0.477	
Wethers	100	21.8	—	31.7±0.482	

* Lambs weighed one day prior to slaughter. These lambs were approximately 1 month younger at slaughter than the Ruakura 1945–6 draft.

† Lambs weighed ten days after docking.

Ram lambs were over 2 lb heavier than ewe lambs at docking and in the Mamaku group the difference had increased to 11½ lb by the time of slaughter. At this stage the ram lambs showed a superiority of 5 lb in live weight over the wether lambs. Although the carcass weights of the rams were heavier than those of the wethers and the wethers were heavier than the ewes, the dressing out percentages were in the reverse order. These results do not entirely agree with those of Hammond,[6] who found that at five months wethers had a higher dressing percentage than either rams or ewes while rams were only slightly lower (0·6 per cent) than ewes. However, his conclusions cannot be taken very seriously in view of the inadequate material (two animals only in each case). The work of Hunt *et al.*[4] supports the author's findings as regards the comparison between rams and wethers. Wallace[2] however found that in bacon pigs of the same weight the male had the highest dressing out percentage, followed by the female, castrate male and castrate female in that order. These results may have been influenced to some degree by the fact that food intake was controlled so that all four members of each set of animals followed the same growth curve, whereas our animals were unrestricted in their feeding so that all sexes had equal opportunity for maximum growth and development on the feed available, and were killed when "fat", regardless of weight.

The opportunity afforded by the experiment of obtaining a measure of testes weight was taken. The mean weight per animal was 236·6 g ± 69 g. This accounts for part of the increased offal loss of ram lambs.

Testes weight bore little relationship to body weight, some of the heaviest lambs having the lightest testicles and *vice versa.*

In spite of the differences in the dressing out percentage the absolute advantage in carcass weight of the rams gives a commercial advantage to the grower.

Effects of Season

As might be expected, seasonal effects were apparent. 1944–5 was a good grass season in the Waikato, while 1945–6 was very poor owing to drought conditions. At Mamaku this season was fairly good. Many workers have shown that male animals are slower to lay on fat than castrates or females. This is reflected in the grading which is summarized in Table II.

Table II. Grading Results as Percentages

Grade:	Prime Down Cross	Prime Cross Bred	Second	Reject
Ruakura 1944–5				
Rams	47	42	11	—
Wethers	66	32	2	—
Ewes	65	35	—	—
Mamaku 1945–6				
Rams	52	22	24	2
Wethers	55	32	9	4
Ewes	57	34	9	1
Ruakura 1945–6				
Rams	6	34	58	2
Wethers	9	57	34	—

Carcass Measurements

The effect of season was apparent chiefly in respect of fat development and, therefore, shows up mainly in the grading results. Since carcass measurements are largely indicative of early developing bone length and muscle depth, season/sex interaction effects were much smaller for these characters and justify bulking of data for Ruakura 1944–5 and Mamaku 1945–6 groups in which all three sex groups are represented. Data for the "poor" season, involving rams and wethers only, are considered separately.

In view of the difference in carcass weight between the sex groups it has been considered advisable to correct measurements for weight where necessary. Only in respect to the width of gigots (G), however, was any marked relationship between carcass weight and measurement found. Other measures varied independently of carcass weight within the range under study. The G-measure alone, therefore, has been been corrected for weight in the tables showing the levels of significance of differences between means (Tables III and V) according to the following regression equations:—

$$\text{Rams:} \quad X = 1.471Y + 181.41$$
$$\text{Wethers:} \quad X = 1.403Y + 178.72$$
$$\text{Ewes:} \quad X = 1.213Y + 187.11$$

where X = width of gigots
Y = carcass weight

In all cases the carcass measurements of the rams exceeded those of the wethers, while those of the wethers exceeded those of the ewes. The differences were most marked in respect of cannon weight and thickness (as shown by $\frac{\text{cannon weight}}{\text{cannon length}}$) the rams

having the heaviest and thickest cannons and the ewes the lightest and finest. Both rams and wethers were appreciably longer in the cannon than the ewes, but the difference between rams and wethers was not so marked, being statistically significant only at the 5 per cent level. This situation is repeated in the length of tibia + tarsus (T). The other leg length measure, depth of crutch (F), takes into account the amount of "filling" in the crutch and is therefore subject to greater variation than the bone length measures, T and M, but is, of course, partly influenced by them. Although the rams were slightly longer in the tibia (T) than the wethers the difference in the F-measurements is not significant—indicating that the ram lambs were rather better filled in the crutch. However, the difference is not very great as the $\frac{F}{T}$ ratio reveals (Table IV). The ewes were shorter in length of tibia (T) than either rams or wethers, but the differences in the F-measurements were only sufficiently marked to be significant in the comparison of rams and ewes, indicating that the ewes were rather less well filled in the crutch than the wethers. The high $\frac{F}{T}$ ratio (Table IV) is due to the short T-measurement rather than to a more desirable short F-measurement.

The rams were substantially wider in the gigots (G) than either the wethers or the ewes, indicating a deeper cut of meat on the leg. The wethers were rather better than the ewes in this respect, although the difference was not so strongly marked.

The mean carcass measurements and level of significance of differences are shown in Table III.

TABLE III. MEAN CARCASS MEASUREMENTS OF RAMS, WETHERS, AND EWES AND LEVEL OF SIGNIFICANCE OF DIFFERENCES

Ruakura 1944–5 and Mamaku 1945–6

Measurement	Rams	Wethers	Ewes
Carcass weight (lb)	36.2	S.	S.S.
		35.1	S.S.
			32.8
Cannon Weight (g)	34.1	S.S.	S.S.
		32.7	S.S.
			28.6
Cannon Length (M) (mm)	106.5	S.	S.S.
		105.3	S.S.
			102.7
Cannon $\frac{Wt}{M}$	32.0	S.S.	S.S.
		31.0	S.S.
			27.9
Width of Gigots (G) (mm)	234.3	S.S.	S.S.
		228.2	S.
			226.8
Depth of Crutch (F) (mm)	235.8	N.S.	S.S.
		233.9	N.S.
			233.3
Length of Tibia+Tarsus (T) (mm)	174.3	S.	S.S.
		172.7	S.S.
			168.7

S.S. = significant at 1 per cent level
S. = significant at 5 per cent level
N.S. = not significant at 5 per cent level

Since there was a difference in carcass weight between the sexes, differences in conformation are best shown by the relationship existing

between the various measures. None of the measurements has been corrected for weight in the following Table or in Table VI.

Table IV. Relationship between Carcass Measurements (as Percentages)

Ruakura 1944–5 and Mamaku 1945–6

	Rams	Wethers	Ewes
$\frac{G}{F}$	98.5	97.8	97.2
$\frac{G}{T}$	133.2	132.4	134.4
$\frac{F}{T}$	135.3	135.4	138.3
$\frac{T}{M}$	163.7	164.0	164.3

While the differences are not very great, it appears that the rams were slightly wider in relation to their depth of crutch ($\frac{G}{F}$) than wethers or ewes, i.e. they had a blockier hindquarters. In the ewes the low $\frac{G}{F}$ ratio and the high $\frac{F}{T}$ ratio indicate poor filling in the crutch, although the high $\frac{G}{T}$ ratio indicates a compact hindquarter. From the ratios of the length of tibia + tarsus to length of cannon ($\frac{T}{M}$) it appears that the upper bone develops in length most rapidly in the ewe and least rapidly in the ram.

The above comparisons between the sexes relate to good and fair seasons since no ewe lambs were available in the bad season. It has been remarked that the fat development of the rams and therefore their grading was adversely affected by poor conditions. Since this was so, the measurements of rams and wethers for this season are shown separately as well as bulked with those of the two other groups for comparison of males and castrates.

Table V. Mean Carcass Measurements of Rams and Wethers and Level of Significance of Differences

	Ruakura 1945–6			*All Seasons*		
Measurement	Rams	Wethers	Significance	Rams	Wethers	Significance
Carcass Weight (lb)	32.6	31.7	N.S.	34.8	33.7	S.
Cannon Weight (g)	31.9	31.1	N.S.	33.2	32.1	S.S.
Cannon Length (M) (mm)	106.5	106.2	N.S.	106.5	105.6	S.
Cannon $\frac{Wt}{M}$	29.9	29.3	N.S.	31.2	30.3	S.S.
Width of Gigots (G) (mm)	229.0	223.4	S.S.	232.2	226.3	S.S.
Depth of Crutch (F) (mm)	240.0	235.5	S.S.	237.5	234.5	S.S.
Length of Tibia+Tarsus (T) (mm)	173.8	171.4	S.S.	174.1	172.2	S.S.

Over all seasons the measurements of the rams exceeded those of the wethers.

From the Ruakura 1945–6 data it appears that the bone thickness development in the ram lambs was retarded in the bad season. Although the mean cannon length was the same for this season as the all-seasons mean, the mean weight, and therefore the weight/length

ratio, was appreciably less. Although the ram lambs averaged 0·9 lb heavier than the wether lambs the difference was not significant.

TABLE VI. RELATIONSHIP BETWEEN CARCASS MEASUREMENTS (AS PERCENTAGES)

	Ruakura 1945–6		*All Seasons*	
	Rams	Wethers	Rams	Wethers
$\frac{G}{F}$	93.5	94.2	96.5	96.4
$\frac{G}{T}$	129.1	129.5	131.6	131.2
$\frac{F}{T}$	138.1	137.4	136.4	136.2
$\frac{T}{M}$	163.2	161.4	163.5	163.1

Differences in conformation between rams and wethers are not so marked when the results over the three different seasons are compared (Table VI). The slight advantage held by the rams in the better seasons (Table IV) has been masked by the inclusion of the bad season. The rams resembled the wethers more closely in the bad season. The effect of season on carcass proportions is illustrated in Tables IV and VI. In bad seasons carcasses are narrower in proportion to leg length and are less "well filled" in the crutch.

Financial Returns

Although the ram lambs were penalized in grading, their slightly greater weight resulted in a greater average return. Table VII shows the average payment for each sex group, on a basis of actual Schedule prices obtaining for the season under consideration.

TABLE VII. AVERAGE RETURNS PER HEAD

	Ruakura 1944–5	Mamaku 1945–6	Ruakura 1945–6
Rams	29/7d	26/5d	24/2d
Wethers	28/11d	26/–d	24/2d
Ewes	26/11d	24/11d	—

These results include the complete drop. In any commercial extension of the practice, late lambs should be castrated. This would increase the return per head from ram lambs and avoid any serious danger of carry-over of unfinished uncastrated animals.

Although the returns from the ram lambs were greater except in the bad drought season, the possibility of a penalty being exacted by the freezing companies to cover the increased cost of slaughter cannot be overlooked. While in good seasons there would probably be some margin of extra profit left, in bad seasons the toll would undoubtedly render the ram lambs less profitable. However, in considering financial aspects the saving of time and labour and reduced risk of loss at docking can also be taken into account.

The extra payment, viz. time and a half, drawn by butchers for dressing ram lambs is, of course, not justifiable on the grounds of extra work and greater difficulty in dressing. It merely results from the fact that mature rams are harder to dress and the premium has long been successfully demanded by butchers for handling such animals. The ram lamb at present suffers in consequence.

Farmer's Experience with Non-castration

In the 1948–49 season a leading local farmer on good class fat-lamb country decided to try out non-castration. He castrated and left entire alternate lambs in each of his two earliest paddocks. The season was very good and the differences were greater than those obtained at Ruakura in previous years. The carcasses were measured up in the usual way. The results are shown below:—

Table VIII. Carcass Measurements and Grading of Ram and Wether Lambs

	Rams	Wethers
Number	104	110
Carcass Weight (lb)	42.4	39.1
Gigot Width (mm)	241.0	235.8
Tibia Length (mm)	177.5	174.5
Crutch Depth (mm)	239.0	235.3
Cannon Weight (g)	37.2	35.0
Cannon Length (mm)	109.7	108.3
Grading		
Down	86	99
Prime	18	11

With the lambs reaching heavier weights the differences between the sexes became more marked and the ram lambs, although carrying less fat than the wether lambs, averaged 3·3 lb heavier. It will also be noted that grading differences were negligible.

Discussion

In general it is apparent that sex influences the rate of growth, carcass weight and dressing-out percentage of lambs. Ram lambs are heavier at docking than ewe lambs and ram lambs attain a heavier slaughter live-weight and carcass-weight than either wether or ewe lambs. The dressing out percentages, however, are in the reverse order, i.e. the percentage of offals, pelt, head and legs, etc., is greatest in the ram lambs and least in the ewe lambs. The weight of the testicles penalizes the ram lambs to a small extent. Financial returns are chiefly influenced by carcass weight, being highest for the rams and lowest for ewes in spite of the disparity in grading.

On grading results there was little difference between wether and ewe lambs, but ram lambs were judged inferior under the existing system, the inferiority being most marked in the bad season when the fat development of the rams was poor. The accepted standards favour a lamb well covered with fat—possibly too well covered from the consumers' point of view. However, the ram lambs were undeniably slightly "coarser" than the other groups, i.e. they were heavier in the bone and therefore thicker in the muscle. With the poorer fat-covering, the muscles of the hindquarters, in particular, tended to stand out somewhat in comparison with those of the normal trade carcass and the shoulders were somewhat thicker. Hence some carcasses were designated by the graders as coarse. It is doubtful whether this was actually a disadvantage and, if so, whether it was sufficiently marked for the majority of consumers to discriminate against them. Unfortunately, it was not possible to conduct any histological examinations or palatability tests. As regards palatability, it must be emphasized that lambs are killed before the age of sexual maturity and there is, therefore, little likelihood of sexual "taint".

In conformation, the ram lambs were somewhat superior to wethers and wethers were superior to ewes, except in the bad season when the rams resembled the wethers more closely in their carcass measurements. Since it is not possible to foretell what the season will bring under New Zealand conditions, a certain risk would be involved under a non-castration policy. The main drawback to non-castration is in the resulting lowering in quality (Table II) if our present grading standards are accepted as representing the consumers' requirements.

Non-castration results in a leaner, somewhat better proportioned, though slightly coarser, carcass under fair to good conditions, but under adverse conditions, e.g. drought, fat development is too poor to meet the demands of "quality" and the conformation of the carcass is no better than that of the castrated male. Hall[9] (referring to females and castrated males) has stated that, commercially, sex is an unimportant factor except in the fancy trade. While this may be so, our results show that at least it is a factor that must be considered in experimental work, and that for fat lamb growers who can be reasonably sure of sending their lambs away as "fats", there are possibilities for the successful adoption of a non-castration policy, at least in respect of early lambs.

Based on the average annual kill of approximately ten and a half million lambs in New Zealand, a conservative estimate of the gross effect of non-castration over approximately two-thirds of the male lambs indicates that over one thousand tons of extra meat would result. An annual effect of this magnitude must receive some consideration in view of the current world food shortage problem and in particular the scarcity of meat in our main market—Great Britain.

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THE EFFECTS OF CHEMICALS AND ANTIBIOTIC SUBSTANCES ON CROWN-GALL (*Agrobacterium tumefaciens* (Smith and Townsend) Conn.)

Part II

By D. W. Dye and P. B. Hutchinson, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

Summary

The antibiotic substances "streptothricin" and "actinomycin" at concentrations equivalent to 50 Oxford units per ml against *S. aureus*, tested on marigold plants under glass, neither prevented gall formation nor retarded their further development.

Acenaphthene in saturated filtered aqueous solution also gave negative results. This material applied as a five per cent solution in dioxane, and full strength dioxane alone, both prevented gall formation and significantly retarded development of previously growing galls. There was no significant difference between five per cent acenaphthene in dioxane and dioxane alone.

Iodine and clove oil solutions caused rapid death of most plants.

There were no significant differences between three methods of application.

In all cases where plants were not killed by treatment, *A. tumefaciens* was reisolated from treated plants.

Introduction

It has been shown (Dye *et al.*, 1950) that colchicine both killed galls on marigolds caused by *A. tumefaciens* and prevented gall formation. Further experiments to investigate the effects of some chemicals, e.g. acenaphthene, dioxane, iodine, clove oil, and antibiotic substances, e.g. streptothricin and actinomycin, have since been carried out.

Literature Review

Waksman *et al.* (1944) used streptothricin in cultural studies against *A. tumefaciens*. They found that a concentration of 1·0 mg per 10 ml reduced the bacterial count from 450×10^3 to $1{\cdot}8 \times 10^3$ and that 0·1 mg per 10 ml reduced the count to $3{\cdot}4 \times 10^3$. They also found that actinomycin having an activity of 10,000,000 *Bacillus subtilis* units at a concentration of 1·0 mg per 10 ml reduced the count from 450×10^3 to less than $0{\cdot}01 \times 10^3$ while the 0·1 concentration reduced the count to $1{\cdot}6 \times 10^3$.

Brown (1941) used acenaphthene at various strengths and in different solvents on bacterial tumors. A five per cent acenaphthene solution in diethylene oxide (dioxan) brushed on 37-day-old galls caused them to shrink and darken, but later they recovered. Dioxan alone, brushed on young and old tumors, produced no discoloration or growth check. A paste of glycerin and acenaphthene spread thickly on galls did not affect these galls nor injure the plants.

Ark (1941) used iodine and clove oil solutions on almond tree tumors with satisfactory results.

Materials and Methods

French marigold plants (*Tagetes patula* L.) were grown in sterilized soil in 4-in pots in a glasshouse, with the air temperature between 60° and 80°F. When the plants were approximately 3-in high they

were divided into two equal groups. One group (Experiment 2) was then inoculated, using the same method as in the earlier experiments (Dye *et al.*, 1950), with a 48-hour beef-peptone-broth culture of a pathogenic strain of *A. tumefaciens*. Forty-eight days later the other group (Experiment 1) was inoculated and plants in both groups were treated.

Treatments

The following materials were used for carrying out the treatments:

1. "Streptothricin",* a culture fluid produced by *Streptomyces lavendulae* having an activity equivalent to 50 Oxford units against *Staphylococcus aureus*.

2. "Actinomycin",* a culture fluid produced by *Actinomyces antibioticus* having an activity equivalent to 50 Oxford units against *S. aureus*.

3. Acenaphthene applied as a

I. Filtered saturated aqueous solution.

II. Five per cent in full strength diethylene dioxide.

4. Diethylene dioxide (Dioxane), full strength.

5. Iodine solution (methyl alcohol, 25 ml; glacial acetic acid, 12·5 ml; glycerine, 12·5 ml; iodine, 5 g).

6. Clove oil solution (methyl alcohol, 20 ml; glacial acetic acid, 10 ml; clove oil, 10 ml).

7. Water.

Three methods of application were used, as previously described (Dye *et al.*, 1950).

A. By injecting the solution into the plants or galls.

B. By smearing the inoculated area or gall with a lanolin-soyabean oil paste containing the solution.†

C. By brushing the solution on to the inoculated stem or gall.

Experiment 1—Treatment at time of inoculation

Immediately after inoculation, plants were treated with the materials using the above three methods. Each treatment was applied to six marigold plants, each plant having two inoculation points.

Experiment 2—Treatment of growing galls

Each treatment was applied to two 48-day-old tumors on each of six marigold plants.

Recording Results

Results of treatments were measured by visible effects on host plants and galls, and by change in size of galls. For the latter, the horizontal diameter of galls was measured with sliding vernier calipers.

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* Culture fluid supplied and assayed by Dr T. R. Vernon, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Auckland. In addition, tests with each of these preparations at 1 ml in 9 ml nutrient agar inhibited the growth of *A. tumifaciens* incubated at 24°C. No growth was apparent after 48 hours, whereas check plates showed good growth.

† Acenaphthene is only slightly soluble in water. To increase the concentration, 1 g crystalline acenaphthene was mixed in 10 ml of the lanolin paste instead of using the aqueous solution of acenaphthene 1. Dioxane when mixed with equal volumes of lanolin reduces this material to a liquid. Hence for acenaphthene II, or dioxane, 10 ml of solution was mixed with 20 ml of lanolin paste. Only 9 ml of both iodine and clove oil solutions could be mixed in the 10 ml of lanolin paste.

In Experiment 1, galls were measured once only, 60 days after treatment. In Experiment 2, galls were measured the day before treatment, and four times after treatment at approximately 14-day intervals.

Reisolation of Crown-gall Organism

In an attempt to recover the pathogen from galls and stems, isolations were made 72 days after treatment. Where the treatment prevented gall development, isolations were made from the stems of plants at the points of inoculation. All bacteria isolated were re-inoculated into stems of young marigold plants.

Results

The results of Experiments 1 and 2 are shown in Tables I and II.

Table I. Effects of Treatments at Time of Inoculation

Treatment.		Effect of treatment on plants. (1)	Number of galls formed (2)	Average horizontal diameters of galls. (cm.)	Mean diameter for material. (cm.)(3)
Material.	Method of application.				
Streptothricin	Injected	No effect	8	0·53	0·84
	Smeared	,, ,,	12	1·12	
	Brushed	,, ,,	12	0·77	
Actinomycin	Injected	,, ,,	10	1·12	1·18
	Smeared	,, ,,	12	1·20	
	Brushed	,, ,,	12	1·32	
Acenaphthene I	Injected	,, ,,	8	1·13	1·10
	Smeared	,, ,,	5	0·97	
	Brushed	,, ,,	12	1·15	
Acenaphthene II (Dioxane soln.)	Injected	Sl. damage	0	0	0·40
	Smeared	No effect	1	0·50	
	Brushed	Sl. damage	1	0·30	
Dioxane	Injected	Sl. damage	2	0·19	0·35
	Smeared	No effect	3	0·37	
	Brushed	Sl. damage	1	0·61	
Iodine solution	Injected	All plants killed	—	—	0·38
	Smeared	2 plants killed	1	0·36	
	Brushed	4 plants killed	1	0·40	
Clove oil solution	Injected	All plants killed	—	—	—
	Smeared	,, ,,	—	—	
	Brushed	,, ,,	—	—	
Water (Control)	Injected	No effect	11	0·85	1·07
	Smeared	,, ,,	12	1·25	
	Brushed	,, ,,	12	1·10	

(1) "Slight damage" was shown by the epidermis being burned where the material was applied; plants were otherwise healthy.
(2) On 6 plants there were 12 points of inoculation, with possibility of 12 galls being formed. Plants were examined 60 days after treatment.
(3) Mean horizontal diameter of galls corrected for 36 galls.

Statistical analysis of the above results show that acenaphthene II and dioxane were, at the one per cent level, significantly superior to water but not different from each other. The remaining materials were not significantly different from water at the five per cent level. Iodine was not included because of plant damage.

TABLE II. EFFECTS OF TREATMENTS APPLIED TO GROWING BACTERIAL GALLS

Treatment.		Effect of treatment on plants.	Average increase per gall. (cm.) (1)	Average increase for material. (cm.) (2)
Material.	Method of application.			
Streptothricin	Injected	No effect	1·06	0·97
	Smeared	,, ,,	0·88	
	Brushed	,, ,,	0·96	
Actinomycin	Injected	,, ,,	1·19	1·15
	Smeared	,, ,,	1·15	
	Brushed	,, ,,	1·12	
Acenaphthene I	Injected	,, ,,	1·14	1·12
	Smeared	,, ,,	0·94	
	Brushed	,, ,,	1·29	
Acenaphthene II (Dioxane soln.)	Injected	,, ,,	0·87	0·79
	Smeared	,, ,,	0·74	
	Brushed	,, ,,	0·76	
Dioxane	Injected	,, ,,	0·53	0·81
	Smeared	,, ,,	1·01	
	Brushed	,, ,,	0·89	
Iodine solution	Injected	5 plants killed	—	—
	Smeared	5 plants killed	—	
	Brushed	All plants killed	—	
Clove oil solution	Injected	All plants killed	—	—
	Smeared	4 plants killed	—	
	Brushed	All plants killed	—	
Water (Control)	Injected	No effect	1·07	1·07
	Smeared	,, ,,	1·08	
	Brushed	,, ,,	1·05	
Difference for significance at 5 per cent level			0·46	0·26

(1) Average increase in horizontal diameter of 12 galls 47 days after treatment.
(2) Average growth increase of 36 galls treated with each material.

It can be seen from the above results that only acenaphthene II and dioxane were significantly different from water, but that they were not different from each other. Also, dioxane injected was significantly different from water injected, and from dioxane smeared.

Results of Reisolations

Viable *A. tumefaciens* was reisolated from plants in all treatments except those involving the use of iodine and clove oil, in which cases isolation was not possible because of the death of the plants.

Conclusions

Of the materials used, only acenaphthene II (five per cent in dioxane), dioxane and iodine prevented the formation of galls and the former two were the only ones which significantly checked the growth of treated galls. Acenaphthene I (filtered, saturated aqueous solution and crystals in lanolin) had little effect on the formation of galls and no effect on the growth of treated galls. Hence the result obtained with acenaphthene II was probably caused by dioxane alone. Brown (1941) found that this material caused no growth check or discoloration of galls, but, of the substances tested in the present experiments, it was the only one showing promise for control of crown-gall on marigolds.

Although Waksman *et al.* (1944) obtained encouraging results with streptothricin and actinomycin in culture, these materials under the conditions of the experiments described above neither prevented gall formation nor retarded the development of growing galls. The use of iodine and clove oil solutions at the concentrations tested on marigolds is not practicable because of the damage they cause to the plants.

There were no significant differences between the three methods of application. The previously established superiority of the lanolin method (Dye *et al.*, 1950) was not maintained. This may be due to the fact that some solutions, especially dioxane, did not mix readily with lanolin.

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NOTE ON SOME INSECT PESTS IN STORED PRODUCTS

By C. H. BELTON, Otago University, Dunedin

(*Received for publication, 18 September 1949*)

During the summer of 1947–8, the author, as part of the original work in Preventive Medicine for the degree of M.B., Ch.B., carried out a brief survey of the insect pests found in stored products in Dunedin.

The survey revealed no positive correlation between insect infestation and public health. No attempt was made to assess the economic significance of the damage caused to foodstuffs.

The original paper, which was presented to Otago University as a thesis, is in the custody of the Department of Preventive Medicine, Medical School, Otago University. It includes a list of some twelve references to previous papers describing investigations carried out on this and related subjects. A collection of specimen insects is held by the Medical School, while a number of duplicate specimens are also available at the Cawthron Institute, Nelson.

The following is a list of the commodities examined and the infesting species:—

COMMODITY	INFESTING SPECIES
Coriander Seed	*Stegobium paniceum* (Syn. *Sitodrepa panicea* Fabre)
	Lariophagus ubitulis? (Parasitic upon *S. paniceum*)
Domestic Flour	*Ptinus tectus*
	Trigonogenius globulus
Mill Flour and Wheat	*Ptinus tectus*
	Trigonogenius globulus
	Ephestia kuhniella
	Tribolium castaneum
	Tribolium confusum
	Calandra granaria
	Calandra oryzae
	Gnathocerus cornutus
	Alphitobius diaperinus
Dates	*Oryzaephilus surinamensis*
Walnuts	*Lathridius* species?
Cocoa	*Ephestia elutella*
	Plodia interpunctella
Semolina	*Trigonogenius globulus*
	Atropos pulsatoria
Bran	*Ptinus tectus*
	Atropos pulsatoria
Cashew Nuts	*Tenebrio mauritanicus*
Raisins	*Hoffmannophilia pseudospretella*
Prunes	*Tribolium confusum*
	Oryzaephilus surinamensis
	Tenebrio mauritanicus
	Carpophilus hemipterus
	Lyctocoris campestris
	Laemophloeus ferrugineus
Silk	*Niptus hololeucus*

The author wishes to thank Sir Charles Hercus, Dean of the Faculty of Medicine, University of Otago, for permission to publish this paper, and Dr. D. Miller, of the Cawthron Institute, Nelson, for the use of laboratory facilities and reference library.

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